

## CLAIMS

1. A recording/reproduction method for recording/reproducing data to/from an optical recording medium including a guiding groove and a recording layer, the recording/reproduction method comprising a step of:

irradiating a laser beam onto the optical recording medium by modulating at least one of a laser irradiation time and a laser irradiation intensity to two or more values;

wherein a  $P_{bi}/P_r$  ratio of a reproduction power ( $P_r$ ) and a bias power ( $P_{bi}$ ) is set to a value that is no less than 0.5;

wherein the data are recorded by constantly providing the laser beam with a power level including the reproduction power ( $P_r$ ) added to the bias power ( $P_{bi}$ ).

2. A recording/reproduction method for recording/reproducing multilevel data to/from an optical recording medium including a guiding groove and a recording layer, the recording/reproduction method comprising a step of:

irradiating a laser beam onto the optical recording medium for recording/reproducing the multilevel data;

wherein the multilevel data are recorded under a condition where a  $D/L$  ratio between a laser beam diameter of  $1/e^2$  of the central intensity of the laser beam ( $D$ ) and a length of

a recording unit of a multilevel recording mark (L) satisfies a relation of  $1 < D/L$ , the recording unit of the multilevel recording mark being a basic cell;

wherein a  $P_{bi}/P_r$  ratio of a reproduction power ( $P_r$ ) and a bias power ( $P_{bi}$ ) is set to a value that is no less than 0.5;

wherein the data are recorded by constantly providing the laser beam with a power level including the reproduction power ( $P_r$ ) added to the bias power ( $P_{bi}$ ).

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3. The recording/reproduction method as claimed in claim 2, wherein the recording is executed by using a strategy in which a  $W_t/L_t$  ratio between an entire pulse time width of a maximum level mark ( $W_t$ ) and a time width of the basic cell length ( $L_t$ ) satisfies a relation of  $0.3 \leq W_t/L_t \leq 0.8$ .

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4. The recording/reproduction method as claimed in claim 3, wherein the recording is executed on the optical recording medium under conditions where the guiding groove has a track pitch ranging from 0.25 to 0.5  $\mu\text{m}$ , a depth ( $D_p$ ) ranging from 15 to 150 nm, an average groove width ( $W_g$ ) ranging from 0.15 to 0.35  $\mu\text{m}$ , and a reflectivity of non-recorded area of the optical recording medium ranges from 2 to 50%, wherein the laser beam is a blue laser with a wavelength that is no more than 450 nm.

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5. The recording/reproduction method as claimed in claim 4, wherein a  $W_g/L$  ratio of the average groove width of the guiding groove ( $W_g$ ) and the length of the recording unit ( $L$ ) satisfies a relation of  $0.7 \leq W_g/L \leq 1.5$ .

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6. The recording/reproduction method as claimed in claim 5, wherein an  $L/D_p$  ratio of the length of the recording unit ( $L$ ) and the depth of the guiding groove ( $D_p$ ) satisfies a relation of  $3 \leq L/D_p \leq 8$ .

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7. The recording/reproduction method as claimed in claim 6, wherein the recording is executed using a strategy including different recording powers of at least two levels.

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8. The recording/reproduction method as claimed in claim 7, wherein the recording power includes two levels and the recording is executed with a strategy in which a  $P_f/P_b$  ratio of a recording power of a former half ( $P_f$ ) and a recording power of a latter half ( $P_b$ ) satisfies a relation of  $0.3 \leq P_f/P_b \leq 1$ .

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9. The recording/reproduction method as claimed in claim 8, wherein the recording power includes two levels and the recording is executed using a strategy which a  $W_b/W_t$  ratio of a pulse time width ( $W_b$ ) and an entire pulse time width ( $W_t$ ) of the

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recording power of the latter half of a maximum level mark satisfies a relation of  $0.3 \leq W_b/W_t \leq 8$ .

10            10. The recording/reproduction method as claimed in  
5   claim 9, wherein the recording is executed by which a switching  
point of the recording power of the former half (Pf) and the  
recording power of the latter half (Pb) corresponds to a center  
of the basic cell.

10            11. The recording/reproduction method as claim 1,  
wherein the recording is executed on the optical recording medium  
having an RO layer including each element of R and O and a thin  
layer of organic material situated on the substrate, wherein R  
includes at least one of the elements selected from a group  
15   including Y, B, I, In, and a lantern series element, wherein O  
expresses oxygen.

             12. The recording/reproduction method as claimed in  
claim 11, wherein the recording is executed on the optical  
20   recording medium in which the RO film includes at least one of  
the elements M chosen from a group including Al, Cr, Mn, Sc, In,  
Ru, Rh, Co, Fe, Cu, Ni, Zn, Li, Si, Ge, Zr, Ti, Hf, Sn, Pb, Mo, V  
and Nb.

25            13. The recording/reproduction method as claimed in

claim 11, wherein the recording is executed on the optical recording medium having a composition that is layered at least with the RO film, the thin film of the organic material, and a reflective layer on the substrate in that order.

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14. The recording/reproduction method as claimed in claim 11, wherein the recording is executed on the optical recording medium having a composition that is layered at least of the reflective layer, the thin film of the organic material, the RO layer, and a cover layer on the substrate in that order.

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15. The recording/reproduction method as claimed in claim 1, wherein the recording is executed on the optical recording medium having an RO layer including each element of R and O and a dielectric layer which has ZnS as the main ingredient above the substrate, wherein R includes at least one of the elements selected from a group including Y, B, I, In, and a lanthan series element, wherein O expresses oxygen.

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16. The recording/reproduction method as claimed in claim 15, wherein the recording is executed on the optical recording medium in which the RO film includes at least one of the elements M chosen from the group including Al, Cr, Mn, Sc, In, Ru, Rh, Co, Fe, Cu, Ni, Zn, Li, Si, Ge, Zr, Ti, Hf, Sn, Pb, Mo, V and Nb.

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17. The recording/reproduction method as claimed in claim 15, wherein the recording is executed on the optical recording medium having a composition that is at least layered  
5 of the RO film, the dielectric layer which has ZnS as the main ingredients, and the reflective layer on the substrate in that order.

18. The recording/reproduction method as claimed in  
10 claim 15, wherein the recording is executed on the optical recording medium having a composition that is at least layered of the reflective layer, the dielectric layer which has ZnS as the main ingredients, the RO layer, and the cover layer on the substrate in that order.

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19. A recording condition determining method for determining recording conditions for recording multilevel data on a track of a recording surface of an optical disk, the recording condition determining method comprising the steps of:

20 a) writing plural of the multilevel data levels having a same value in a plurality of test areas, each of the test areas having a prescribed length in a direction of a line tangent to the track, the prescribed length being greater than a spot diameter of an optical spot formed on the track; and

25 b) obtaining a suitable recording power and recording

strategy in accordance with the levels of reproduction signals generated from the test areas.

20. The recording condition determining method as  
5 claimed in claim 19, wherein the suitable recording power and the recording strategy are obtained when the difference between a greatest value and a least value of the levels of reproductions signals is no more than a reference value.

10 21. The recording condition determining method as claimed in claim 20, wherein the reference value is recorded in the optical disk.

22. The recording condition determining method as  
15 claimed in claim 20, further comprising a step of:

c) determining the type of the optical disk;

wherein the reference value is selected from predetermined values in accordance with the type of the optical disk.

20 23. The recording condition determining method as claimed in claim 20, wherein the reference value includes a value obtained by calculating a formula of  $\{|DR|/\{\gamma \cdot (\alpha - 1)\}\}$ , wherein  $\alpha$  is a value of the multilevel data which is no less than  
25 3, DR is the difference between a reproduction signal level of

an unrecorded area and a reproduction signal level of an area in which a largest mark is recorded, and  $\gamma$  is a value no less than 1.

5           24. The recording condition determining method as claimed in claim 23, wherein the multilevel data include multilevel data corresponding to the largest mark, wherein the reference value is obtained by referring to the reproduction signals generated from the test areas.

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25. The recording condition determining method as claimed in claim 19, wherein the suitable recording power and the recording strategy are obtained when an average value of the levels of the reproduction signals falls within a predetermined range.

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26. The recording condition determining method as claimed in claim 19, wherein the suitable recording power and the recording strategy are obtained when the difference between at least one of the greatest value of the levels of the reproduction signals and the least value of the levels of the reproduction signals, and an average value of the levels of the reproduction signals is no more than a predetermined reference value.

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27. The recording condition determining method as claimed in claim 19, wherein the number of multilevel data levels

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recorded in the test areas is set to satisfy a formula of

$$\beta = A + 2,$$

wherein  $\beta$  represents the number of multilevel data levels recorded in the test area, wherein A represents an integer when

5 a calculation result of  $2R \div S$  is rounded up, wherein 2R represents the spot diameter of the optical spot, wherein S represents the length of the test area.

28. The recording condition determining method as  
10 claimed in claim 27, wherein the levels of reproduction signals generated from the test areas are derived by omitting the multilevel values of a foremost test area and a rearmost test area obtained by rounding down a calculation result of  $R \div S$ , respectively.

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29. A recording method for recording multileveled data on a track of a recording surface of an optical disk, the recording method comprising a step of:

recording the multilevel data on the track of the  
20 recording surface of the optical disk by using the suitable recording power and the recording strategy obtained in claim 1.

30. An optical disk apparatus for recording multilevel data on a track of a recording surface of an optical  
25 disk, the optical disk apparatus comprising:

a writing part for writing plural of the multilevel data levels having a same value in a plurality of test areas, each of the test areas having a prescribed length in a direction of a line tangent to the track, the prescribed length being greater than a spot diameter of an optical spot formed on the track;

an obtaining part for obtaining a suitable recording power and recording strategy in accordance with the levels of reproduction signals generated from the test areas; and

a recording part for recording the multilevel data on the track of the recording surface of the optical disk by using the obtained recording power and recording strategy.

31. The optical disk apparatus as claimed in claim 30, wherein the suitable recording power and the recording strategy are obtained when the difference between a greatest value and a least value of the levels of reproductions signals is no more than a reference value.

32. The optical disk apparatus as claimed in claim 31, wherein the reference value is recorded in the optical disk.

33. The optical disk apparatus as claimed in claim 31, further comprising:

a determining part for determining the type of the optical disk;

wherein the reference value is selected from predetermined values in accordance with the type of the optical disk.

5                   34. The optical disk apparatus as claimed in claim 31, wherein the reference value includes a value obtained by calculating a formula of  $\{ |DR| / \{ \gamma \cdot (\alpha - 1) \} \}$ , wherein  $\alpha$  is a value of the multilevel data which is no less than 3, DR is the difference between a reproduction signal level of  
10 an unrecorded area and a reproduction signal level of an area in which a largest mark is recorded, and  $\gamma$  is a value no less than 1.

                  35. The optical disk apparatus as claimed in claim  
15 34, wherein the multilevel data include multilevel data corresponding to the largest mark, wherein the reference value is obtained by referring to the reproduction signals generated from the test areas.

20                   36. The optical disk apparatus as claimed in claim 35, wherein the recording part further records the obtained reference value in the optical disk.

                  37. The optical disk apparatus as claimed in claim  
25 30, wherein the suitable recording power and the recording

strategy are obtained when an average value of the levels of the reproduction signals falls within a predetermined range.

38. The optical disk apparatus as claimed in claim  
5 30, wherein the suitable recording power and the recording  
strategy are obtained when the difference between at least one  
of the greatest value of the levels of the reproduction signals  
and the least value of the levels of the reproduction signals,  
and an average value of the levels of the reproduction signals  
10 is no more than a predetermined reference value.

39. The optical disk apparatus as claimed in claim  
30, wherein the number of multilevel data levels recorded in the  
test areas is set to satisfy a formula of  
15  $\beta = A + 2$ ,  
wherein  $\beta$  represents the number of multilevel data levels  
recorded in the test area, wherein A represents an integer when  
a calculation result of  $2R \div S$  is rounded up, wherein 2R  
represents the spot diameter of the optical spot, wherein S  
20 represents the length of the test area.

40. The optical disk apparatus as claimed in claim  
39, wherein the levels of reproduction signals generated from the  
test areas are derived by omitting the multilevel values of a  
25 foremost test area and a rearmost test area obtained by rounding

down a calculation result of  $R \div S$ , respectively.

41. A program used for an optical disk apparatus operable to record multilevel data on a track of a recording surface of an optical disk, the program comprising:

a writing process for writing plural of the multilevel data levels having a same value in a plurality of test areas, each of the test areas having a prescribed length in a direction of a line tangent to the track, the prescribed length being greater than a spot diameter of an optical spot formed on the track;

an obtaining process for obtaining a suitable recording power and recording strategy in accordance with the levels of reproduction signals generated from the test areas; and

a recording process for recording the multilevel data on the track of the recording surface of the optical disk by using the obtained recording power and recording strategy.

42. A computer-readable recording medium comprising:

the program as claimed in claim 41.

43. A recording method for recording data on a recording layer of an optical disk, the recording method comprising the steps of:

a) preheating the recording layer to a temperature

less than an initial mark forming temperature by irradiating at least a single preheat pulse onto the optical disk, the preheat pulse having a power level that is greater than a reproduction power for the optical disk and less than a recording power for the optical disk;

b) heating the recording layer to a temperature equal to or greater than the initial mark forming temperature by irradiating at least a single main pulse onto the optical disk; the main pulse having a power level the same as the recording power for the optical disk.

44. The recording method as claimed in claim 43, wherein the preheat pulse has a power level that is no more than 80% of the recording power.

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45. The recording method as claimed in claim 43, wherein the preheat pulse includes a first pulse and a second pulse, wherein the first pulse has a power level that is different from a power level of the second pulse.

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46. The recording method as claimed in claim 45, wherein one of the first pulse and the second pulse has a power level that is no more than 40% of the recording power.

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47. The recording method as claimed in claim 43,

wherein the data recorded in the optical disk includes at least one of binarized data and multilevel data having three or more values.

5                   48. The recording method as claimed in claim 47, wherein when the data recorded to the optical disk are binarized data, step a) is executed when a mark among the marks formed on the recording layer is shortest.

10                   49. The recording method as claimed in claim 43, wherein the main pulse includes at least a single pulse.

                  50. The recording method as claimed in claim 43, wherein the temperature of the recording layer has a point where  
15   temperature suddenly changes before reaching the initial mark forming temperature.

                  51. The recording method as claimed in claim 50, wherein the temperature of the recording layer has no point where  
20   temperature suddenly changes after the temperature of the recording layer is no less than the initial mark forming temperature.

                  52. An optical disk apparatus for recording data on  
25   a recording layer of an optical disk, the optical disk apparatus

comprising:

an optical pickup apparatus for irradiating a laser light by employing pulse emission;

preheating part for preheating the recording layer  
5 to a temperature less than an initial mark forming temperature by irradiating at least a single preheat pulse onto the optical disk, the preheat pulse having a power level that is greater than a reproduction power for the optical disk and less than a recording power for the optical disk;

10 a heating part for heating the recording layer to a temperature equal to or greater than the initial mark forming temperature by irradiating at least a single main pulse onto the optical disk; the main pulse having a power level the same as the recording power for the optical disk.

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53. The optical disk apparatus as claimed in claim 52, wherein the preheat pulse has a power level that is no more than 80% of the recording power.

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54. The optical disk apparatus as claimed in claim 52, wherein the preheat pulse includes a first pulse and a second pulse, wherein the first pulse has a power level that is different from a power level of the second pulse.

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55. The optical disk apparatus as claimed in claim



54, wherein one of the first pulse and the second pulse has a power level that is no more than 40% of the recording power.

56. The optical disk apparatus as claimed in claim  
5 52, wherein the data recorded in the optical disk includes at least one of binarized data and multilevel data having three or more values.

57. The optical disk apparatus as claimed in claim  
10 56, wherein when the data recorded to the optical disk are binarized data, the preheating is executed when a mark among the marks formed on the recording layer is shortest.

58. The optical disk apparatus as claimed in claim  
15 52, wherein the main pulse includes at least a single pulse.

59. The optical disk apparatus as claimed in claim  
52, wherein the temperature of the recording layer has a point where temperature suddenly changes before reaching the initial  
20 mark forming temperature.

60. The optical disk apparatus as claimed in claim 59, wherein  
the temperature of the recording layer has no point where  
temperature suddenly changes after the temperature of the  
25 recording layer is no less than the initial mark forming

temperature.